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Morpho-Syntactic Load in Judging Adjective Plural Agreement: Comparing Adults With and Without ADHD

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Abstract

The study examined the impact of two grammatical factors on marking Hebrew adjectives in agreement with plural nouns in adults with attention-deficit hyperactivity disorder (ADHD) compared with peers without ADHD. Participants were 36 adult speakers of Hebrew, who were administered a judgment test of 144 sentences, each containing an adjective in agreement with a plural noun in one of three different syntactic configurations—predicative adjectives, attributive adjectives in sentence–initial position, and attributive adjectives in sentence–final position. Noun suffixes were regular, semiregular (ambiguous), and irregular. Findings showed that participants with ADHD displayed lower accuracy and longer response time compared with controls. As morphological and morpho-syntactic difficulty simultaneously increased, participants with ADHD were significantly more likely to perform less well compared with controls on both accuracy and speed. These findings indicate that adults with ADHD might be suffering from a linguistic impairment exacerbated under more cognitively and linguistically demanding conditions.

Keywords

adult, age, language, assessment, disorders, communication, cultural/linguistic, diversity, ADD/ADHD, exceptionalities, syntax, language/linguistics

Introduction

Attention-deficit hyperactivity disorder (ADHD) is a childhood neurobehavioral disorder that is often expressed in inattentive behavior, hyperactivity, and impulsivity (*Diagnostic and Statistical Manual of Mental Disorders* [5th ed.; *DSM-5*]; American Psychiatric Association [APA], 2013). The disorder affects a significant minority of at least 6% of children and often persists into adolescence and adulthood (Engelhardt, Ferreira, & Nigg, 2011a, 2011b; Kessler et al., 2006). Research indicates that children with ADHD are easily distracted by extraneous stimuli and therefore miss verbal, nonverbal, and social cues, resulting in poor social functioning, lower academic achievements, and, later in life, lower occupational attainment (Mapou, 2009; Wolf & Wasserstein, 2001).

Studies investigating children with ADHD have shown that they often exhibit difficulties in academic skills (Petersen et al., 2013; Tirosh & Cohen, 1998; Westby & Watson, 2004). These impairments relate to reading comprehension (Samuelsson, Lundberg, & Herkner, 2004), listening comprehension (McInnes, Humphries, Hogg-Johnson, & Tannock, 2003), expressive language abilities (Purvis & Tannock, 1997; Snowling, Bishop, Stothard, Chipchase, & Kaplan, 2006; Stevenson, Pennington, Gilger, DeFries, & Gillis, 1993; van Lambalgen, van Kruistum, & Parigger, 2008), and mathematical skills (Stolzenberg & Cherkes-Julkowski, 1991).

While the literature supports an association between ADHD and academic skills in children, results of studies in the 1990s were mixed regarding linguistic performance in child and adolescent ADHD. Thus, studies showed that children with ADHD demonstrated language difficulties in different linguistic areas, especially in spoken expressive tasks administered under elicited conditions (Barkley, DuPaul, & McMurray, 1990; Barkley, Murphy, & Bush, 2001; Zentall, 1988). However, no differences were reported between children with ADHD and typically developing children as far as their phonological skills are concerned (Samuelsson et al., 2004), and no significant difference was found between children with ADHD and controls on oral language expressive and receptive abilities (Javorsky, 1996).

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The current literature strongly supports an association between ADHD and language disorders, based on both oral and written language testing (Cohen et al., 2000; Geurts et al., 2004; Rohrer-Baumgartner et al., 2013). It has produced evidence pointing at the co-occurrence of expressive and receptive language problems in children with ADHD when compared with their typically developing counterparts (DaParma, Geffner, & Martin, 2011; Helland, Posserud, Helland, Heimann, & Lundervold, 2012; Sharma, Purdy, & Kelly, 2009). For example, when orally producing verb tense affixes and connectivity between utterances, children with ADHD utilized a complexity-reducing strategy (van Lambalgen et al., 2008). Children with ADHD also scored lower than typically developing children on oral sentence imitation and word articulation tests (O. H. Kim & Kaiser, 2000), indicating a delay in processing abstract verbal information (Hurks et al., 2004) and a lower efficiency in word learning (Cutting, Koth, Mahone, & Denckla, 2003). Recent studies found Children with ADHD to have extensive pragmatic problems in the organization of coherent spoken discourse (Green, Johnson, & Bretherton, 2014), to be much slower on complex sentence comprehension than peers (Wassenberg et al., 2010), and to display deficits in various aspects of oral story narration (Renz et al., 2003). From the perspective of written language, Children with ADHD were found to engage in less desirable behaviors in producing written texts (Mathers, 2006) and to produce less grammatically intricate written texts (Mathers, 2005).

Less clear is what aspect of language skills these problems produce in adults. To our best knowledge, few studies have investigated language production of adults with ADHD. Gregg, Coleman, Stennett, and Davis (2002) examined word and sentence-level features in the expository writing of college students with learning disabilities (LD), ADHD, LD + ADHD, and controls. Results showed that while all the groups used the same text dimensions, they differed in the extent to which specific features contributed to each dimension. The study indicated that overall, the holistic quality rating (content/organization, style, sentence structure, and conventions), verbosity, and type/token ratio scores for writers with ADHD were significantly low compared with participants without disabilities. Relatedly, adults with ADHD, similar to children with ADHD, demonstrated difficulties in organizing and monitoring story retelling and off-topic interruptions during conversation (Purvis & Tannock, 1997). Two new studies by Engelhardt et al. (2011a, 2011b) examined oral language production in adults with ADHD and non-ADHD controls, as well as with adults who had ADHD as children but no longer met ADHD criteria. In producing verbal descriptions, adults with ADHD used less effective and fluent language than that of controls, indicating difficulty in the planning, managing, and production levels of this particular task. In constructing active and passive sentences, grammatical and fluent production was impaired in adults with ADHD as well as in those in whom ADHD did not persist. Finally, K. Kim, Lee, and Lee (2013), explored the differences in the written language styles of college students with and without ADHD symptoms. Their data show a significant decrease in the use of complex sentences, clauses per sentence, morpheme per sentence, and numeral pronouns in the samples of the ADHD students. However, they produced more sentences and adjectives compared with their non-ADHD cohorts.

Due to methodological variation, the generalizability of the above studies is limited. The majority of previous work used language production tasks that elicited conversation or else instructed participants to retell a story or give instructions. Other studies used structured language elicitation, but no study to date has examined morphological and syntactic abilities of adults with ADHD using a structured experimental method of oral elicitation.

Against this background, the current study examines whether language difficulties extend to grammaticality judgment in adults with ADHD, systematically investigating the role of morphological and syntactic factors in judging the marking of Hebrew adjectives in agreement with plural nouns. Based on the language production literature, we hypothesize that under demanding conditions, participants with ADHD would make more errors when judging the grammaticality of a complex morpho-syntactic task of assigning Hebrew plural agreement to adjectives. If indeed a difference exists between the two groups, it would suggest that the language problem of individuals with ADHD also affects metalinguistic abilities such as grammaticality judgment (Karmiloff-Smith, 1992; Ravid, 2009; Ravid & Malenky, 2001).

Plural Marking in Hebrew

Plural marking (e.g., English book/books) is an example of inflectional morphology, which organizes grammatical information in language-specific conventionalized ways (Slobin, 2001). In a language with rich inflectional morphology such as Hebrew, nouns are marked for plural number and adjectives are marked in plural agreement with nouns in the same noun phrase (e.g., *the big* fences) and as predicates in the sentence (e.g., the fences are *big*). As adjectives are dependent on nouns, regularity or irregularity of plural marking on nouns directly affects plural agreement marking on adjectives.

Plural marking is characterized crosslinguistically by high token frequency, general and obligatory applicability (Bybee, 1985; Dressler, 2012), so that plurals are prominent and frequent in language usage. At the same time, plural systems in many languages typically manifest morphological irregularities (Ravid, 1995; Ravid et al., 2008). For example, English *mouse* changes to *mice* in the plural instead of taking the regular suffix *–s*. In Hebrew too, marking the plural form of nouns can be either regular or irregular. Hebrew nouns are regularly pluralized by adding a

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plural suffix to the singular form, which is marked phonologically as either masculine or feminine (Ravid & Schiff, 2009). Regular nouns phonologically marked as masculine, such as *sir* "pot," take the plural suffix *–im*, as *sirim* "pots." Regular nouns phonologically marked as feminine, such as *sira* "boat," take the plural suffix *–ot*, as in *sirot* "boats."

Nonregular plural suffixation in Hebrew has two subtypes. One is *irregular* suffixation, where nouns take the opposite gender suffix despite the clear marking on the singular noun. For example, the irregular masculine noun *sulam* "ladder" takes the feminine suffix *–ot* to yield plural *sulamot* "ladders" (where *sulamim* would be expected), and the irregular feminine noun *mila* "word" takes the masculine plural *–im* to yield *milim* "words" (where *milot* would be expected). A second type of nonregular suffixation results from *ambiguous singular noun phonology*, which makes it difficult for speakers to determine singular noun gender. For example, *gader* "fence" has masculine phonology but is in fact feminine, while *yalkut* "sachel" has feminine phonology but is in fact masculine. Taken together, these two types of nonregular nouns constitute stumbling blocks to correct plural marking, especially in populations with language problems (Schiff & Ravid, 2012).

Plural Marking on Hebrew Adjectives

The current study focuses on testing plural number marking on adjectives in agreement with nouns. Adjectives follow nouns in Hebrew and agree with them in gender and number. For example, masculine noun *sirim* "pots" should be followed by *levanim* "white" with the same *–im* plural marking; and feminine noun *sirot* "boats" should be followed by *levanot* "white" with the same *–ot* plural marking. Therefore, adjective pluralization does not require the involvement of a semantic component, but it does require knowledge of noun gender and plural noun suffixation. Even for straightforward cases of regular inflection, marking plural agreement on the adjective is not a simple task. It requires the simultaneous representation of two entities—the noun and the adjective, with choice of adjective plural suffix being informed by noun gender. Plural agreement is thus a procedure of scanning the plural noun phrase, determining the gender of the head noun, taking note of the phonology of its plural suffix, and marking the adjective accordingly.

However, in cases of nonregular plural noun suffixation, the difficulty of adjective marking is exacerbated. When the noun takes irregular suffixation (e.g., masculine *kir* "wall" taking the irregular feminine plural suffix *–ot*), the adjective marking must ignore this irregular suffix and follow the inherent gender of the noun. The plural phrase "white walls" would then be *kirot levanim* "walls white," with conflicting suffixes on the noun and on the adjective. In cases of ambiguous singular noun phonology such as feminine *gader* "fence" having masculine phonology, correct adjective marking requires taking into account the singular and plural form of the noun as well as its inherent gender. The current study makes use of the three noun suffix types—regular, irregular, and ambiguous—in marking plural agreement of adjectives with nouns. We termed the ambiguous suffixes semiregular.

Syntactic Position of the Adjective

In addition to the morphological variable of noun regularity, the study examines plural adjective agreement in conjunction with syntactic adjective position. Adjectives can take one of two major syntactic positions, as sentence predicates or as noun modifiers. Adjectives that serve as sentence predicates are termed *predicative adjectives*, as in the example "The thoughts of the child were *happy*." Adjectives that serve as modifiers in the noun phrase are termed *attributive adjectives*, as in "The child had [*happy* thoughts]." Due to the variability in Hebrew word order constructions (Berman, 1980; Ravid, 1995), noun phrases with attributive adjectives may appear in two different sentential positions—at sentence-initial and sentence-final positions. Thus, *ha-maxshavot* ha-smexot *hayu be-roshi* "the *happy* thoughts were in my mind" has an initial noun phrase with an attributive adjective, while *la-ish hayu maxshavot* smexot "to-the-man were *happy* thoughts = the man had happy thoughts" has a final noun phrase with an attributive adjective.

The current study examined the impact of suffix regularity and adjective syntactic position on judgment of adjective agreement with plural nouns in adults with and without ADHD. In judging the correctness of plural adjective agreement, attention needs to be paid both to the morphological properties of the head noun and to their expression in the plural adjective. We thus expected this task to be harder for the ADHD participants. Moreover, given that agreement computation relies on a limited scope of planning (Gillespie & Pearlmutter, 2011), it made sense to expect predicative adjectives to be more difficult to process than attributive adjectives, due to distance between subject and predicate. Regarding attributive adjectives, we predicted agreement to be easier and more accurate in the final noun phrase than in the initial noun phrase. Finally, we expected the combined load of suffix nonregularity and the differential syntactic position of the plural adjective to be more challenging for the ADHD participants. The meaning of such an expected finding is that for adults with ADHD, the limited simultaneous management of complex linguistic processing might have its roots in a language disorder of a higher order.

Method

Participants were 71 Israeli adults, monolingual native speakers of Hebrew, of whom 35 (18 men and 17 women) were undergraduate students with ADHD (age M = 26.67, SD = 7.46), diagnosed by their university disability service

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Table 1. Demographic and Diagnostic Information by Group.

	Group						
	TD (n = 36)		ADHD (n = 35)				
Variable	*M*	*SD*	*M*	*SD*	*df*	*t*	*p*
Vocabulary	10.61	1.37	10.65	1.75	69	−0.11	.91
WR_accuracy	108.37	4.14	103.89	4.23	69	4.51	<.001
WR_speed	83.03	5.83	82.94	5.88	69	0.06	.95
NWR_speed	54.86	4.98	55.71	4.40	69	−0.77	.45
NWR_accuracy	38.78	4.20	39.03	4.34	69	−0.25	.81
Digit span	12.64	2.76	10.05	3.06	69	3.74	<.001
Omissions	4.78	2.14	7.80	1.80	69	−6.44	<.001
Commissions	13.72	5.93	17.20	4.56	69	−2.77	.007
Hit RT	337.70	69.62	384.26	62.50	69	−2.96	.004
Hit RT *SE*	6.18	1.84	7.89	3.11	55	−2.81	.007

Note. TD = typically developing; ADHD = attention-deficit hyperactivity disorder; WR = Word Reading; NWR = Nonword Reading; RT = reaction time.

center, and 36 (18 men and 18 women) controls without ADHD (age M = 25.82, SD = 5.32). The ADHD group included 20 sophomores and 15 juniors with the following division of majors: 6 Sociology, 8 Psychology, 11 Brain Sciences, and 10 Education majors. The control group consisted of 20 sophomores and 16 juniors, and their division of fields of specializations was as follows: 7 Law, 8 Psychology, 11 Brain Sciences, and 10 Education majors. Participants in both groups were undergraduate students attending Bar Ilan University, Tel Aviv University, and the Hebrew University in Jerusalem, all from mid- to high socioeconomic status (SES) background, with no overt emotional problems, and with normal hearing and sight (or sight corrected by spectacles). All participants had passing grades for the courses, taken in the last semester.

Participants with ADHD were randomly selected and recruited from Bar Ilan, Tel Aviv, and the Hebrew university, with their ADHD diagnosis screened by the researchers. To make sure that these participants had been diagnosed in childhood with ADHD and to verify that they were still struggling with ADHD symptoms, the disability service centers in which they had been diagnosed with ADHD provided us with their files containing the Brown attention deficit disorder (ADD) questionnaire (Brown & Gammon, 1991), a detailed anamnesis (medical and psychiatric case history), a clinical interview by a psychiatrist (based on the *Diagnostic and Statistical Manual of Mental Disorders* [4th ed.; *DSM-IV*; APA, 1994] criteria), and a physical checkup.

In addition, only participants who were currently using the ADHD-related medication used in Israel, Ritalin LA or Concerta (Generic name: methylphenidate), participated in the study, and all underwent a washout period of at least 24 hr prior to testing. This degree of washout is considered sufficient to minimize medication effects on results.

The control group of students with no ADHD consisted of age, year of study, and major-matched undergraduate student recruited using Internet websites and bulletin boards at three major universities in Israel (Tel Aviv, Bar Ilan, and the Hebrew University in Jerusalem) and across the country. We ended up having students only from Bar Ilan in the control group. They all agreed to participate in the study by signing a consent form.

To verify the group division, all participants took the Continuous Performance Test (CPT; Conners & MHS Staff, 2000) requiring the participant to respond to a sequence of visual stimuli while ignoring distracting stimuli. Performance was evaluated using the number of omissions, commissions, mean reaction time (RT) on hit trials, and mean standard deviation of RTs on these trials. The ADHD group had significantly more omission and commission errors, and their mean response time and mean standard deviation of RTs on hit trials were all significantly higher compared with controls (see Table 1). In other words, the ADHD group performed more poorly than the control group on all four CPT measures.

In addition, all the participants completed the paper-and-pencil Adult Self-Report Scale (ASRS-v1.1; Kessler et al., 2005), which was translated into Hebrew and approved by the World Health Organization as the official Hebrew version. The scale has excellent reliability and validity (Zohar & Confortes, 2010). Results show that the two groups differed in the frequency and severity of hyperactivity/impulsivity and inattentiveness as the ADHD group scored higher on all ADHD symptoms compared with the controls (see Table 2).

To assure that they had no reading disability, participants were also administered four reading tests (Schiff & Kahta, 2006): (a) Word Reading Accuracy, (b) Word Reading Speed, (c) Nonword Reading Accuracy, and (d) Nonword Reading Speed. All participants underwent the Wechsler

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Table 2. ASRS Diagnostic Information by Group.

	Group						
	TD (n = 36)		ADHD (n = 35)				
Variable	*M*	*SD*	*M*	*SD*	*df*	*t*	*p*
ASRS six items	2.38	0.89	3.55	1.42	57.0	−4.14	<.001
ASRS_HA	23.03	2.81	27.17	5.81	48.8	−3.81	<.001
ASRS_IA	23.00	2.66	31.26	6.61	44.5	−6.87	<.001
ASRS_TOT	46.03	5.34	58.43	8.68	56.2	−7.22	<.001

Note. ASRS = Adult Self-Report Scale; TD = typically developing; ADHD = attention-deficit hyperactivity disorder; ASRS_HA = Adult Self-Report Scale, Hyperactive group; ASRS_IA = Adult Self-Report Scale, Inattentive group; ASRS_TOT = Adult Self-Report Scale, Total.

Adult Intelligence Scale (WAIS) Vocabulary and the Digit Span subtest. Results show that the two groups did not differ in their vocabulary and reading abilities, except for the word reading accuracy test on which the ADHD group performed lower than the controls but still within the normal range. In accordance with meta-analytical and experimental studies (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Rapport et al., 2008), scoring on the WAIS Digit Span subtest demonstrated that the ADHD group performed lower than the controls (see Table 1).

Finally, to eliminate the possibility of working memory interference, a series of Pearson correlations were carried out, examining the relation between Working Memory scoring and RT and Accuracy. Most of the values were approximately zero and none of them was statistically significant ($p > .05$). Accordingly, we inferred that working memory did not play a significant role in the performance on the judgment task; hence, this variable was not included in subsequent analyses.

Instruments consisted of the Judgment Task which required participants to judge the correctness of 144 sentences that were read aloud, each containing a plural adjective in agreement with a noun. Half of the 144 Judgment Task sentences were grammatical, that is, the adjective was in correct agreement with the head noun, and half ungrammatical, so that the adjective was incorrectly marked.

Piloting of components, structure, and instructions was undertaken among 10 pilot participants to ensure uniformity and exclude confounding variables, with subsequent corrections and revisions of the materials. Sentences were recorded with the help of a professional technician on the SuperLab computer software.

Item Selection

Altogether, 48 nouns and 16 adjectives were used in the task to create noun–adjective sets for each sentence. The irregular and ambiguous (semiregular) nouns selected for the task consisted of the exhaustive list on the official Hebrew Language Academy site at https://www.safa-ivrit.org/irregulars/index.php—so that, in fact, we used all Hebrew irregular nouns listed. The rest of the nouns on the task were regular. They all ranked between 2 and 3 (out of 10) on the Noun Scale (Ravid, 2006), which scores nouns on a scale of abstractness from very concrete nouns (ranked 1–2) to abstract, morphologically complex nominals (ranked 7–10). In addition, these nouns ranked no more than 2 on a 3-point familiarity scale by 30 native-speaking students (not the same participants who were eventually administered the Judgment Task). Adjectives selected for the task belonged to the core adjectival lexicon of Hebrew as designated in Ravid and Levie (2010). All sentences contained 10 to 14 syllables so as to control for sentence length that might affect working memory. Finally, we minimized the occurrence of gender markers in the sentence. For example, we used the gender-neutral plural past tense copula hayu "were" rather than the gender-specific plural present tense copula *hem* (masculine) or *hen* (feminine) "are."

Table 3 presents the structure of the task. The 144 sentences were divided by three noun suffix type—regular, irregular, and ambiguous (semiregular). The sentences were also divided by adjective's syntactic position: sentence-initial attributive adjective (*ha-kosot ha-shkufot hayu ba-pina* "the transparent cups were in the corner"); sentence-final attributive adjective (*le-Netan'el hayu kosot shkufot* "Nathaniel had transparent cups"); and a predicative adjective (*ha-kosot ba-pina hayu shkufot* "the cups in the corner were transparent") in agreement with a plural subject noun. The same noun–adjective set occurred in all three positions.

Procedure

The task was preceded by four training items of grammatical and ungrammatical sentences with adjectives, requiring correct/incorrect decisions. After training, the actual experiment started. Instructions were as follows: "You will hear a series of sentences. Some of the sentences are correct and some are incorrect. You have to determine for each sentence whether it is correct or incorrect and press the appropriate button." Randomized stimuli were presented orally by the SuperLab software program, which also recorded the response selected and marked the onset of the participant's response, and, separately, by student researchers who had undergone training by the two authors. To ensure students' full attention, the Judgment task was administered in three parts, each containing a randomized list of items, on three consecutive days.

Scoring

Judgment measures were Accuracy (correct response on sentence grammaticality) and RT to Correct Response in milliseconds. All scores were converted to percentages. Where necessary, we conducted Bonferroni post hoc

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Table 3. Structure of the Judgment Task.

	Syntactic position of adjective		
Noun suffix type	Adjective in attributive-initial position *N* = 48	Adjective in attributive-final position *N* = 48	Predicative adjective *N* = 48
Regular suffix	*n* = 16	*n* = 16	*n* = 16
Ambiguous suffix (Semiregular)	*n* = 16	*n* = 16	*n* = 16
Irregular suffix	*n* = 16	*n* = 16	*n* = 16

pairwise comparisons to determine significant differences and sources of interactions.

Results

A three-way mixed ANOVA was conducted separately on RTs and correct responses, with position (attributive-initial, attributive-final, and predicative) and suffix (regular, ambiguous [semiregular], and irregular) as within-subjects factors and group (ADHD, controls) as a between-subjects factor. These analyses yielded a significant main effect of position for RT, $F(2, 138) = 9.88$, $p < .001$, partial $\eta^2 = .13$, and for accuracy, $F(2, 138) = 12.05$, $p < .001$, partial $\eta^2 = .15$. Post hoc comparisons using Bonferroni adjustment ($p < .05$) revealed that grammatical judgment for the attributive-initial position was more difficult than for any other position. This was evidenced by significantly longer RT (M = 1,719.13, SD = 831.31) and reduced accuracy (M = 91.29, SD = 6.84) for attributive-initial adjectives than for the attributive-end position (M = 1,495.82, SD = 580.76 and M = 93.77, SD = 5.33 for RT and accuracy, respectively), on one hand, and longer RT ($p = .058$) than for the predicative position, on the other. Responses to sentences with attributive-final adjectives tended to be faster ($p = .055$) and more accurate than to sentences with predicative adjectives (M = 1,627.76, SD = 787.41 and M = 92.03, SD = 7.36, respectively).

There was also a significant main effect of suffix, $F(2, 138) = 44.79$, $p < .001$, partial $\eta^2 = .39$ for RT and $F(2, 138) = 46.29$, $p < .001$, partial $\eta^2 = .40$ for accuracy. Post hoc comparisons using Bonferroni adjustment ($p < .05$) demonstrated that responses to adjectives in agreement with nouns carrying ambiguous (semiregular) and irregular suffixes were longer (M = 1,708.79, SD = 867.79 and M = 1,774.76, SD = 716.33, respectively) and less accurate (M = 86.63, SD = 7.25 and M = 89.44, SD = 11.08, respectively) on average compared with regular suffixes (M = 1,359.15, SD = 630.70 and M = 98.02, SD = 3.07 for RT and accuracy, respectively). The analyses yielded a significant main effect of group, $F(1, 69) = 9.04$, $p = .004$, partial $\eta^2 = .12$ for RT and $F(1, 69) = 8.44$, $p = .005$, partial $\eta^2 = .11$ for accuracy. Students with ADHD were slower (M = 1,766.75, SD = 670.76) and less accurate (M = 90.60, SD = 6.55) compared with controls (M = 1,373.67, SD = 400.82 and M = 94.45, SD = 4.44, respectively).

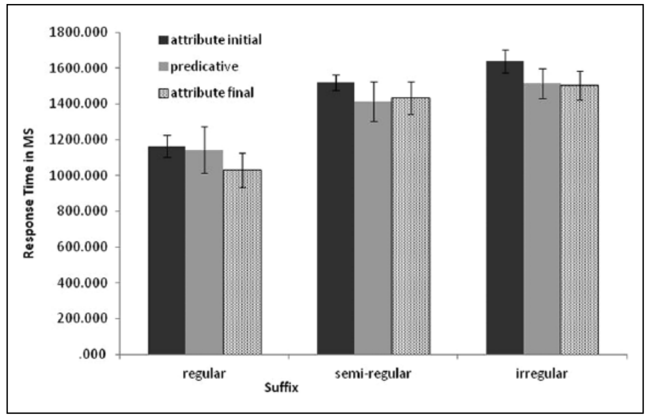

Figure 1. Reaction time in the control group as a function of position and suffix.

In addition to these, there was a significant position by suffix interaction for both RT, $F(4, 276) = 2.88$, $p = .02$, partial $\eta^2 = .04$, and accuracy, $F(4, 276) = 11.40$, $p < .001$, partial $\eta^2 = .14$, and a significant position by group interaction for accuracy, $F(2, 138) = 5.11$, $p = .007$, partial $\eta^2 = .07$. These interactions were qualified by a three-way position × suffix × group interaction that was significant for both RT, $F(4, 276) = 3.20$, $p = .01$, partial $\eta^2 = .04$, and accuracy, $F(4, 276) = 5.44$, $p < .001$, partial $\eta^2 = .07$. To further explore this interaction, the two-way position × suffix interactions (see Figures 1 and 2) were examined in each group separately.

For RTs, there was no significant interaction in the control group, $F(4, 140) < 1$. As shown in Figure 1 and confirmed statistically by post hoc comparisons with Bonferroni adjustment ($p < .05$), RT was shorter for regular suffixes compared with both ambiguous (semiregular) and irregular suffixes. Furthermore, RT for the attributive-initial position was longer on average than both the attributive-final and predicative in this group. In contrast, in the ADHD group the two-way interaction was significant, $F(4, 136) = 3.89$, $p = .005$. Simple effect analyses indicated that for ambiguous (semiregular) suffixes, RT for the attributive-initial position was longer compared with both the attribute-final and predicative

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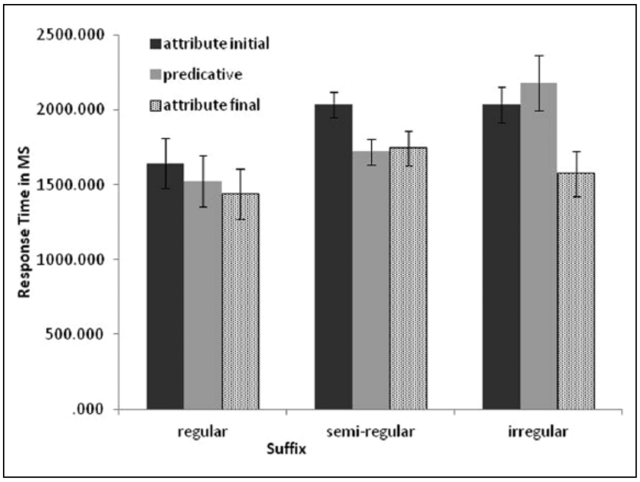

Figure 2. Reaction time in the ADHD group as a function of position and suffix.

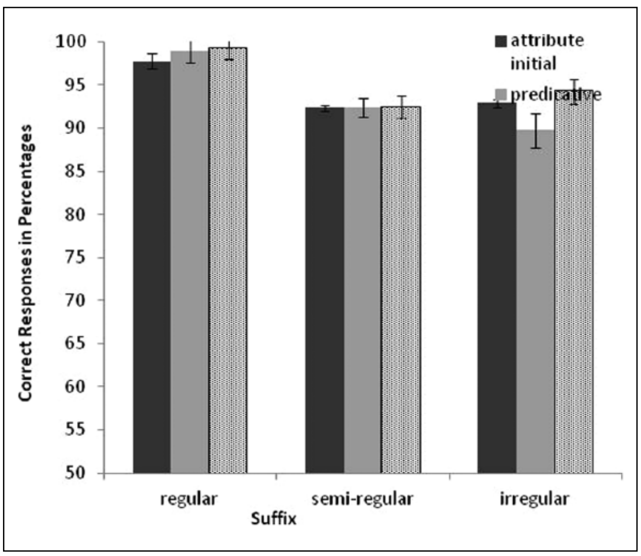

Figure 3. Accuracy in the control group as a function of position and suffix.

positions. For irregular suffixes, RT for both the attributive-initial and predicative positions was longer than the attribute-final (for means and standard errors, see Figure 2).

Unlike the RTs, the two-way interaction for accuracy was significant in the control group, $F(4, 140) = 2.58$, $p = .04$ (see Figure 3). Simple effect analyses revealed no differences between the three positions except for irregular suffixes, for which responses were less accurate when yielded for the predicative compared with the attributive-final positions (see Figure 3 for means and standard errors). For example, consider *pninim yafot* "beautiful pearls," where the adjective *yafot* carries a plural suffix adhering to the inherent gender but not to the irregular suffix of the

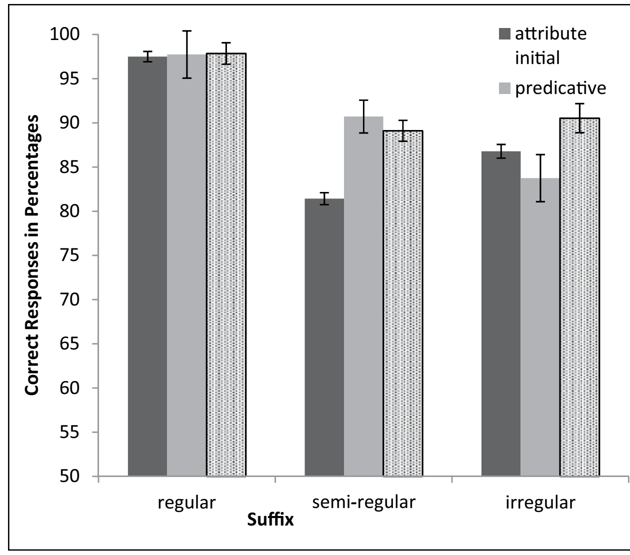

Figure 4. Accuracy in the ADHD group as a function of position and suffix.

noun. When this adjective was in the predicative position as in "the pearls in the drawer were *beautiful*," scores were lower than when it was in the attributive-final position, as in "in the drawer were *beautiful* pearls." This interaction was significant in the ADHD group too, $F(4, 136) = 12.98$, $p < .001$ (see Figure 4). Simple effect analyses revealed significant differences in accuracy for ambiguous (semiregular) and irregular suffices. Complementing the RT results, responses for the attributive-initial position (e.g., "the *quiet* cities were at the border") were less accurate than for both the attributive-final ("at the border were *quiet* cities") and predicative positions ("The cities at the border were *quiet*") in the context of ambiguous (semiregular) suffixes, and less accurate for both the attributive-initial and predicative positions than for the attributive-final position.

Discussion

The current study examined the impact of two grammatical factors on marking Hebrew adjectives in agreement with plural nouns—(ir)regularity of noun suffix and syntactic position of adjective in the sentence. As the study participants were adults with ADHD compared with adults without ADHD, these factors defined the morpho-syntactic arena that affected their performance. Being a judgment rather than a production task, the instrument required participants to reflect about the grammaticality of sentences hosting adjectives in three different structures—including those that might have been very difficult to elicit in a production task, such as attributive-initial adjectives. In this position, representation of information about noun gender and phonological marking together with adjective marking

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needs to be continuously maintained from the beginning of the sentence to its end, with other candidates for agreement in the way. For example, the noun *border* at the end of the sentence "the *quiet* cities were at the border" might interfere with judging the noun–adjective pair at the beginning of the sentence. In addition, the notion of morphological irregularity was extended from irregular lexical exceptions to ambiguous (semiregular) suffixes. Moreover, this design broadened the scope of grammatical investigation from the effect of plural noun morphology (suffix regularity) to the syntactic function of the adjective (attributive vs. predicative) and the site in which attributive adjectives appeared (sentence-initial vs. sentence-final).

Two facets of the results stand out for both groups. One has to do with the syntactic position of the adjective in the sentence and the other with its morpho-syntactic properties. First, results overall showed that grammatical judgment for the attributive-initial position (what would be in English, for example, "The *short* fences were in the yard) was more difficult than for two other positions—attributive-final ("In the yard there were *short* fences") and predicative ("The fences in the yard were *short*"); and that responses to attributive-final stimuli ("In the yard there were *short* fences") tended to be faster. Maintaining number-gender agreement within noun–adjective pairs as well as across the sentence from subject to predicate is more difficult for participants with ADHD, who are more likely to be distracted by intervening linguistic material across the sentence. Populations with language-based deficiencies, such as people with dyslexia, might also find the attributive-initial position more challenging (Schiff & Ravid, 2012). These findings point to the importance of word order and distance from the agreement-conferring noun as important factors in syntactic agreement. All participants found it difficult to retain information about agreement processing from its implementation at sentence-initial position to agreement judgment at its end, due to the intervening material (e.g., *the yard*) constituting competition for the role of agreement source. Predicative adjectives were not as difficult to inflect, given that on one hand information about the agreement source noun had to be retained across intervening material, but on the other hand predicates normally occur at the end of the sentence. This is also why attributive-final responses were overall faster, as both noun and adjective were adjacent to each other and also appeared at sentence-end position.

A second general finding indicated that the responses of both groups to adjectives carrying ambiguous (semiregular) and irregular suffixes were longer and less accurate than to nouns with regular suffixes. Regular plural suffixes on nouns follow the inherent gender of the singular noun—that is, plural masculine nouns take the suffix *–im* and plural feminine nouns take the suffix *–ot.* Moreover, regular plural suffixes are in line with singular noun phonology—that is, with the phonological markers of gender on the singular noun. Plural agreement of adjectives in all syntactic positions needs to adhere to inherent noun gender while taking into account its singular phonology, on one hand, and plural suffix choice, on the other, both of which might be in clash with inherent noun gender. Our results show that unclear, contradictory, and inconsistent marking of number/gender on nouns is detrimental to plural adjective agreement in both groups.

The effects of conflicting morpho-syntactic factors were exacerbated in the ADHD group, indicating the role of the combination of morphological irregularity and syntactic complexity in the language processing of adults with attention deficits. Overall, students with ADHD were slower and less accurate compared with controls, and even more importantly, when the types of grammatical demands increased simultaneously, participants with ADHD were significantly more likely to perform less well compared with controls on both accuracy and speed. When adjectives agreed with regular noun suffixes, both groups performed similarly on Accuracy and RT regardless of position in the sentence. However, the ADHD group made more errors in the ambiguous (semiregular) suffix condition, where singular noun phonology is in clash with inherent noun gender, requiring more time in the most difficult attributive-initial position. The irregular suffix as the most difficult morphological condition elicited a decrease of accuracy in the ADHD group as well as an increase in RT for both attributive-initial and predicative adjective positions. This may indicate that the processing demands requiring attention to both noun phonology and gender, in conjunction with the requirement to implement agreement with adjectives at difficult sentence positions, were extremely challenging for the ADHD students due to a developmental language deviance or a disorder.

Results of this study, pointing at poorer performance on a task requiring morpho-syntactic knowledge, are in line with previous studies showing that the language of adults with ADHD is substantially less complex and more disfluent compared with their counterparts without ADHD (Gregg et al., 2002; K. Kim, Lee, & Lee, 2013). Using a structured task with controlled load manipulation, the current study shows that the linguistic impairment found in adults with ADHD as demonstrated by the grammaticality judgment tasks is exacerbated under more cognitively demanding conditions. The finding that judgment of the regular suffix remained constant in the different syntactic positions but differed when two facets of linguistic difficulty were manipulated (morphology and syntax) indicates that it is the simultaneous management of complex linguistic processing that is the issue. This integration of functions is exactly the type of executive ability that challenges individuals with ADHD. While coping with separate levels of difficulty might be possible, coping with their combined complexity was poor, perhaps due to poor regulation of competing

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responses (response inhibition), lack of an alert state, poor anticipation of the necessary timing of the functional components, or other breakdowns in the executive or control domain (Nigg, 2005).

The judgment task used in the current study required a higher order skill, that is, the conscious or explicit application of thought processes to linguistic structures (Gleitman & Gleitman, 1979; Ravid & Hora, 2009; Weskott & Fanselow, 2011). Our results support findings from past studies by suggesting that ADHD is also linked to a language disorder of a higher order that had its genesis in early childhood. We propose that such higher order skills are dependent on attentional capacity, which makes sense considering that complex language processing involves cognitive load management. Thus, when adults with ADHD performed the task that was attentionally demanding, the reduction of resources available for processing the different aspects of the task limited access to explicit grammatical reflection, expressed in decreased performance. We suggest that directly manipulating the load of a cognitive language task is a key issue in understanding the linguistic performance of adults with ADHD.

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